

# ASPECTS OF SUPERCRITICAL TURBULENCE: DIRECT NUMERICAL SIMULATION OF AN $O_2/H_2$ TEMPORAL MIXING LAYER

N. A. Okong'o, K. G. Harstad and J. Bellan

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, CA 91109-8099

Direct Numerical Simulations of a supercritical oxygen/hydrogen ( $O_2/H_2$ ) temporal three-dimensional mixing layer are conducted for the purpose of exploring the features of high-pressure transitional mixing behavior. The conservation equations, formulated according to fluctuation-dissipation theory and coupled to a modified Peng-Robinson equation of state, comprise a model that has been previously validated in the context of fluid drop behavior. The mixing layer boundary conditions are periodic in the streamwise and spanwise directions, and of non-reflecting outflow type in the cross-stream direction. Simulations are conducted with initial Reynolds numbers of 600 and 750, initial pressure of 100atm and temperatures of 400K in the  $O_2$  and 600K in the  $H_2$  stream, and with accurately correlated Schmidt and Prandtl numbers. Each simulation encompasses a perturbation-induced rollup and two pairings of four initial spanwise vortices into a single vortex. The layer eventually exhibits distorted regions of high-density gradient magnitude (HDGM) similar to the experimentally observed wisps of fluid at the boundary of supercritical jets. Analysis of the data reveals that the higher Reynolds number layer reaches transition, whereas the other one does not. The transitional layer is analyzed to elucidate its characteristics. The composition of the HDGM regions is explored and it is found that they are composed of  $O_2$  with  $H_2$  dissolved into it. As one probes deeper into the HDGM regions, the  $O_2$  mass fraction increases. HDGM regions of a specified percentage of the maximum density gradient magnitude achieved within a layer contain approximately the same mass fraction of  $O_2$  (the heavier fluid), independent of the wavelength of the initial perturbation. Moreover, the mass fraction of the heavier fluid is approximately the same for heptane/nitrogen, which is another species system investigated. In contrast with atmospheric turbulence, it is found that the dissipation is overwhelmingly dominated by the species mass flux, with minimal viscous contribution, independent of the species system.